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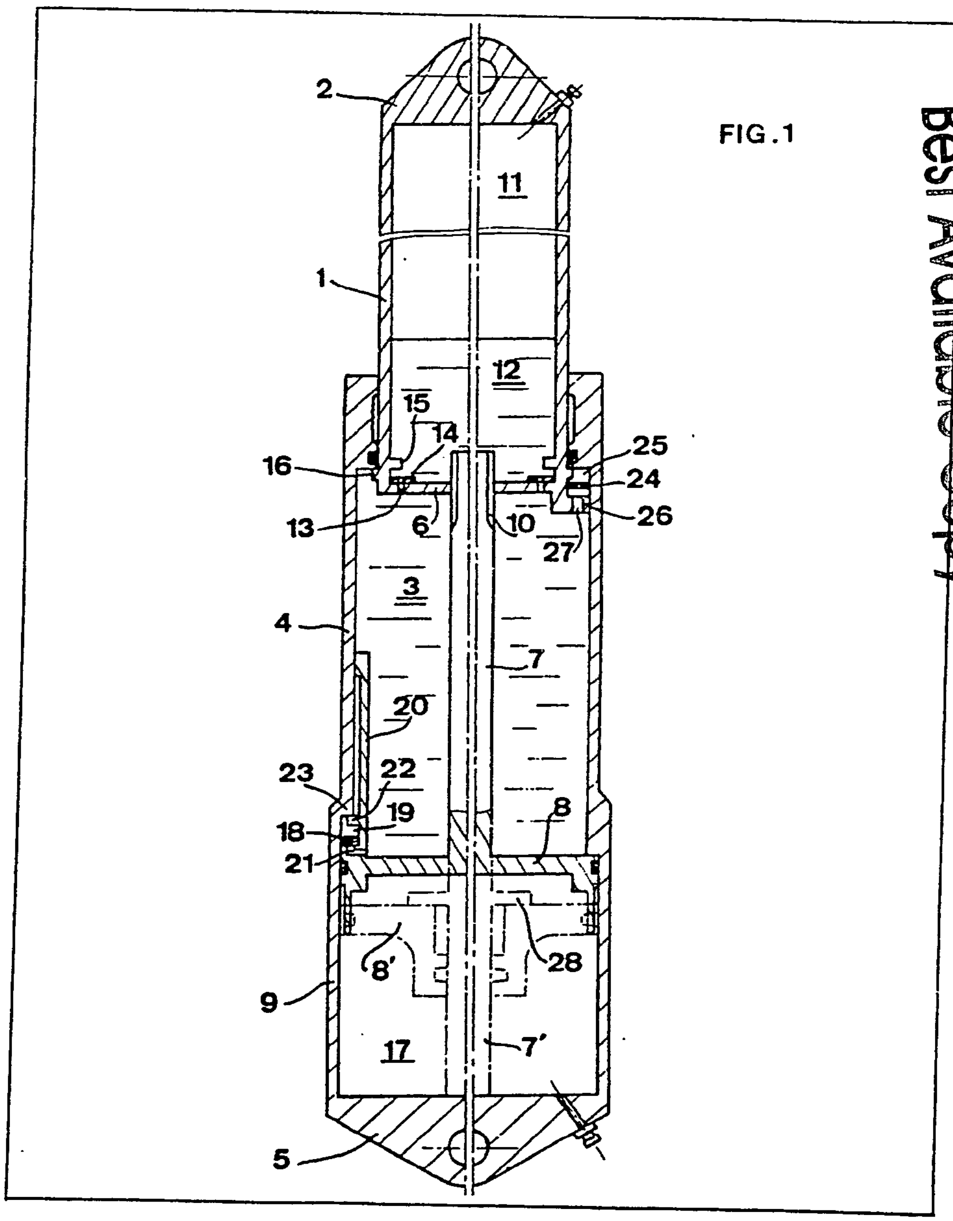
(71) Applicants
Messier-Hispano-Bugatti, 5 rue Louis Lejeune, 92120 Montrouge, France
(72) Inventors
Jean Masclet,
Andre Turiot
(74) Agents
D. Young & Co., 10 Staple Inn, London WC1V 7RD

(54) Suspension dampers for aircraft undercarriage

(57) A suspension damper particularly suitable for a helicopter undercarriage comprises a damper rod 1 containing a low-pressure resilient return chamber 11 and slideable in a chamber 3 of a cylinder 4 which is filled with oil. The pressure of the oil in the chamber 3 is applied to a movable wall 8 which itself bears against a force threshold element 17 (e.g. gas at high pressure) permitting movement of the movable wall 8, when the damper is subjected to a compression load as from a force higher than a given threshold, and independently of the speed of inward movement of the damper rod 1 into the cylinder 4. Movement of the rod 1 and piston 6 is damped by valve controlled orifices 13.



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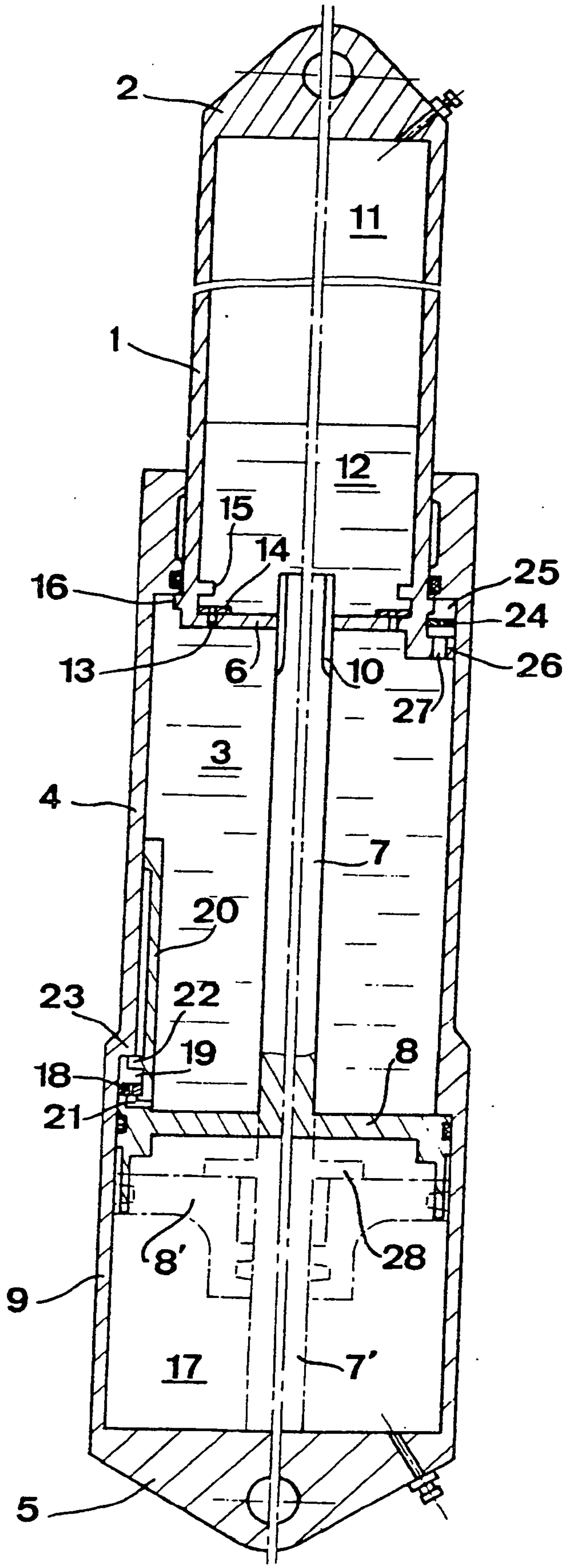

FIG.1

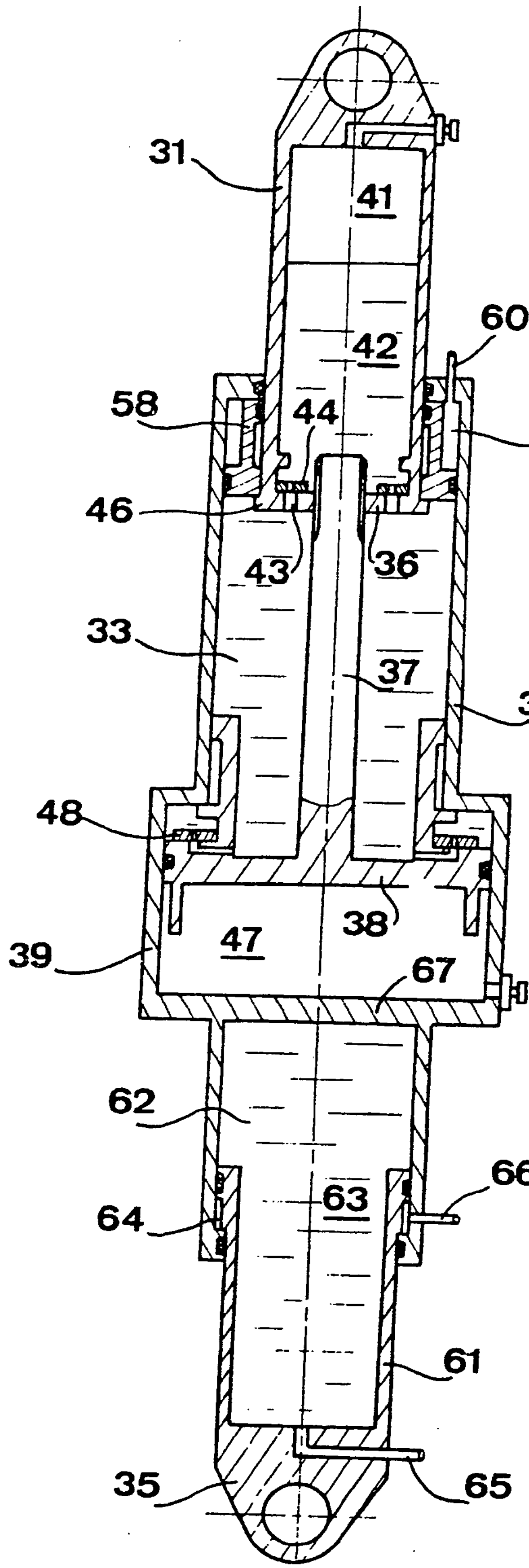
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FIG. 2

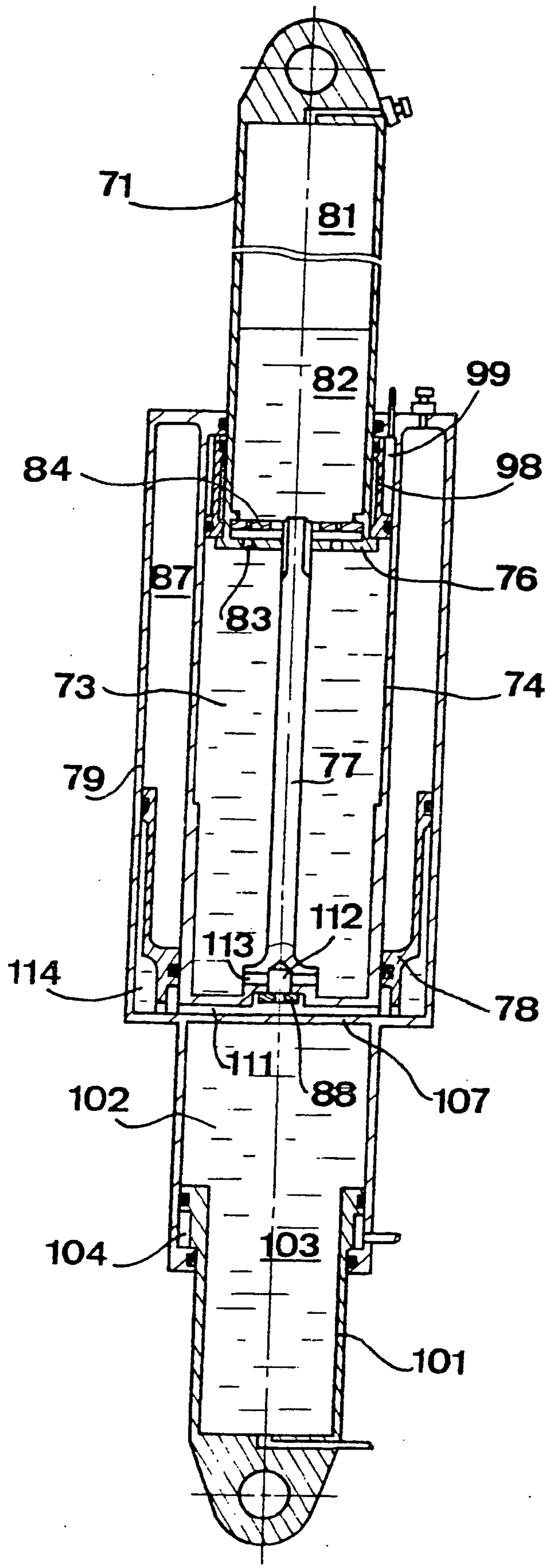
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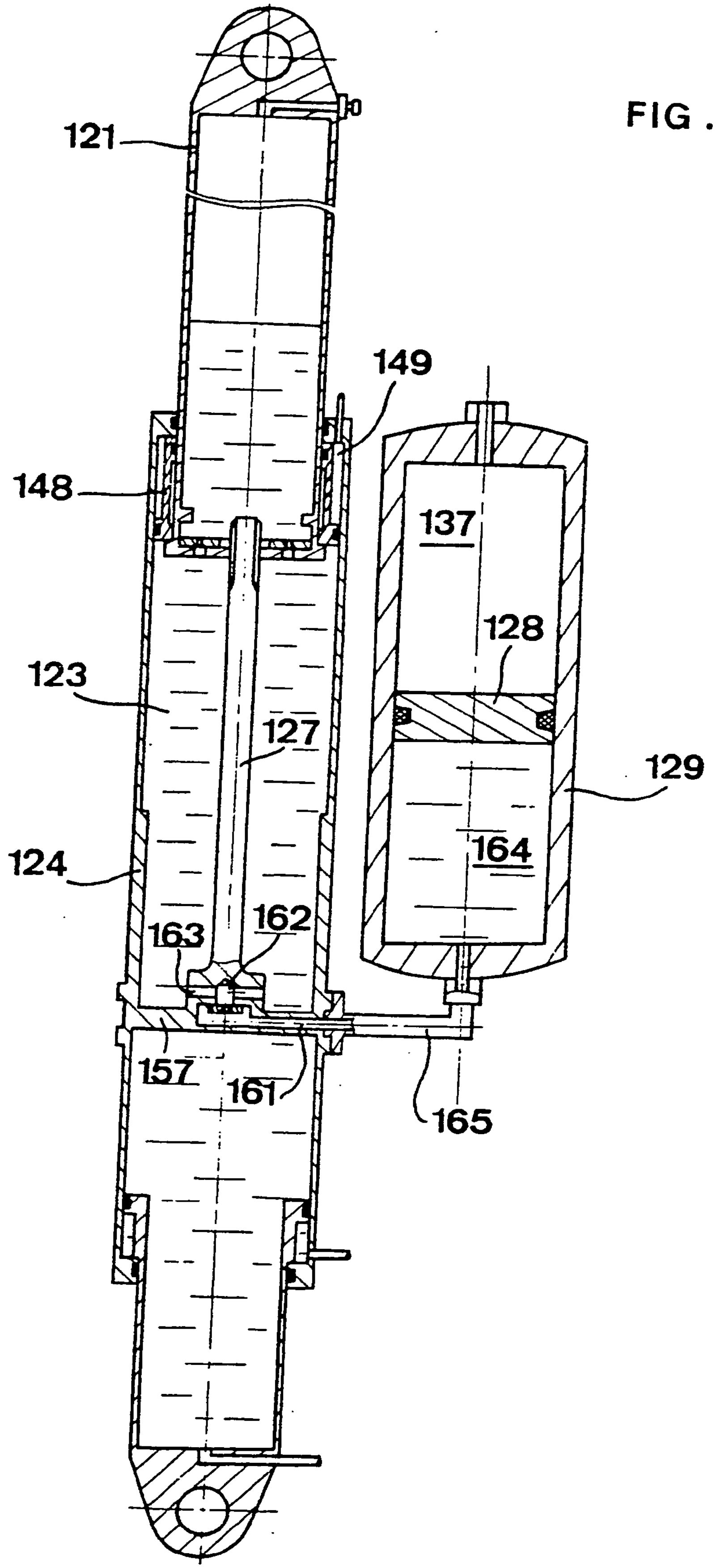
FIG. 3

FIG. 4



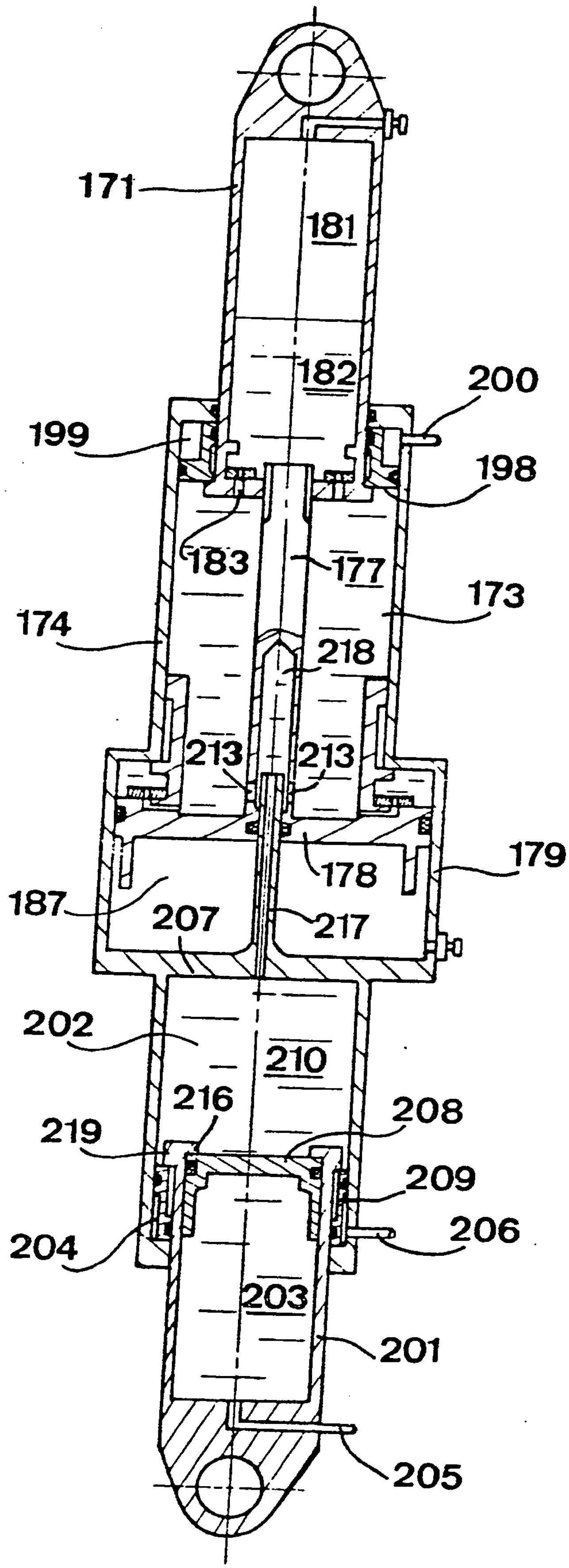

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FIG. 5

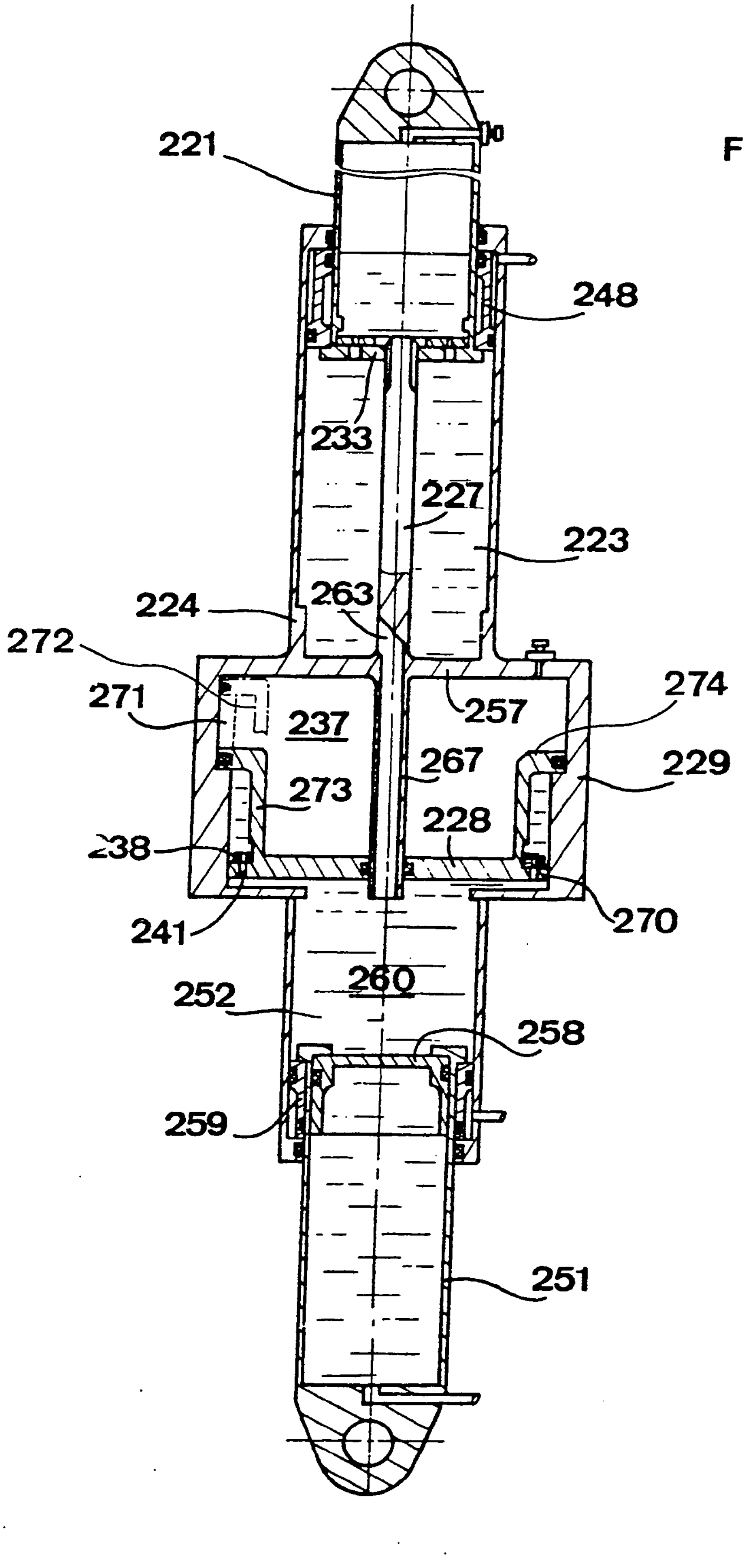
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FIG. 6

SPECIFICATION

Suspension dampers and damper jack assemblies particularly for aircraft undercarriage trains

The invention relates to dampers and damper jack assemblies and particularly to suspension dampers of the kind used on aircraft undercarriage trains, in particular for helicopters, and which can permit landings under disaster conditions, that is to say "crash landings".

Various kinds of suspension dampers for aircraft undercarriage trains have been previously proposed comprising a damper rod which is mounted slideably and sealingly within a first hydraulic fluid chamber of a cylinder, the rod or the cylinder containing a low-pressure resilient return chamber such as a pressure gas chamber, and a volume of hydraulic fluid which is possibly adjacent to the low-pressure chamber and which is in communication with a first chamber of the cylinder by at least one compression mode throttle orifice which is provided for example by a piston carried by the end of the damper rod which is received within the cylinder, expansion of the low-pressure chamber being retarded by an expansion throttle valve.

In these dampers, the low-pressure chamber acts as a spring for returning the arrangement to the equilibrium position after damping of the movement of the rod in the cylinder has occurred by dissipation of energy by throttling of the hydraulic fluid through orifices which are calibrated for normal vertical landing speeds, of the order of 3 m/s, making it possible for the energy upon impact to be absorbed.

Some of the previously proposed dampers also comprise valves which are provided with throttle orifices of variable section depending on the speed of retraction movement or the direction of flow of the fluid, and means for producing a braking action at the end of expansion of the damper, in order to make the damper effective when the aircraft is taxying on ground surfaces which have not been prepared or on runways which are paved with slabs, or to absorb certain force peaks, in order to absorb the effects of the phenomenon of ground resonance, which occurs with helicopters, at the limit of the supporting action, just before take-off, and in order not to allow the arrangement to expand abruptly, with a shock when it reaches a limit abutment position in the expanded condition.

However, these previously proposed dampers are found not to be suited to crash landings or crashing of the aircraft, with vertical speeds of the order of from 10 to 12 m/s, in respect of which the compression-mode throttle orifices appear to be under-dimensioned so that the damper behaves like a virtually rigid element and transmits to the aircraft structure all of the forces which it receives, which causes destruction of the aircraft or destruction of the damper which in turn results in destruction of the aircraft.

Other publications have also disclosed a damper of this kind, wherein the throttle orifice is determined by a piston through which there passes, with a defined clearance, a rod carried by a rigid end portion which is mounted within the rod and which is itself apertured with braking orifices providing for throttling of the hydraulic fluid passing from a chamber within the rod towards a chamber which is within the rigid end portion and which is separated from a high-pressure gas chamber by a separating piston.

Upon impact, in the above-described arrangement, and in similar arrangements which have a movable end portion apertured with throttle orifices, superimposed on the forces due to the inertia of the non-suspended components such as the wheel and the accessory equipment thereof (in particular brakes), are forces which are due to the throttle action and which increase in proportion to increases in the vertical speed upon impact, so that the total force to which the damper is subjected is very much greater than its limit elastic load and can exceed its breaking load or the breaking load of the undercarriage, and result in the aircraft being destroyed.

Damper jack assemblies have also been proposed which are capable of moving the undercarriages between a retracted position when the aircraft is in flight, an extended position for landing and taxying and a position of being "dropped", that is to say with the aircraft lowered closer to the ground than it is with the undercarriage extended, to facilitate housing the aircraft in a hanger, accessibility to certain parts of the aircraft, loading the aircraft or anchoring the aircraft in a parking area. Damper jack assemblies described in other documents made available to the public comprise a damper which can be of the kind set forth hereinbefore, and mounted at the end of a jack rod of which a first chamber acts as a cylinder for the damper, and is itself fixed with respect to a jack piston which is mounted slideably in a jack cylinder, with which the piston defines a chamber for controlling the downward movement of the undercarriage train when it is supplied with hydraulic fluid and for controlling the "dropped" positioning when it is emptied, without change in the load of the damper. Moreover, a raising piston which is mounted slideably in a second chamber of the jack rod, which is separate from the first chamber and which forms a chamber for raising the undercarriage, makes it possible for the damper to be loaded by pulling the rod of the damper inwardly of the rod of the jack when the second chamber is supplied with hydraulic fluid and the lowering chamber is emptied, which moves the undercarriage into the retracted position. A mechanical locking device for example of claw type or of hydraulic kind, comprising a controlled-opening hydraulic locking valve, is also provided for locking the jack rod in the extended position with respect to the jack cylinder, after filling of the lowering chamber. In the case of a hydraulic arrangement, an over-pressure valve which is disposed at the bottom of the lowering chamber permits extension of the travel movement by

emptying of the lowering chamber in the event of a crash landing. However, this solution suffers from the disadvantage that the possible travel movement of the damper is not put to the best use for absorbing an additional part of the crash landing energy.

The problem with which the present invention is concerned is that of providing suspension dampers which are capable of absorbing a fraction of the crash landing energy which can be from three to four times the normal maximum energy absorbed in respect of normal landing speeds, the above-mentioned fraction of crash landing energy being itself absorbed at speeds which are three to four times higher than the normal speeds, and the complementary fraction of the crash landing energy being absorbed by the structure of the aircraft carrying the dampers or damper jack assemblies, which latter are to be destroyed only after having utilised all their travel movement in the compression mode, irrespective of the vertical speed of the aircraft with respect to the ground, with the force to which the damper is subjected remaining close to the elastic limit load and in any event lower than the extreme load, namely the breaking load of the undercarriage or the damper.

According to the present invention there is provided a suspension damper comprising a damper rod which is mounted slideably and sealingly within a first hydraulic fluid chamber of a cylinder and which contains a low-pressure resilient return chamber adjacent to a volume of hydraulic fluid which is in communication with the first chamber of the cylinder by way of at least one compression-mode throttle orifice provided in a piston carried by the end of the damper rod which is inward of the cylinder, expansion of the low-pressure return chamber being braked by an expansion-mode throttle valve, wherein the hydraulic fluid pressure obtaining in the first chamber is applied to a movable end portion which itself bears against a force threshold element permitting a travel movement of the movable end portion, when the damper is subjected to a compression load, as from a force greater than a given threshold, and independently of the speed of inward movement of the damper rod into the cylinder.

Such a suspension damper has particular application to an aircraft undercarriage train.

The force threshold element may be in very different forms, ranging from a pressure gas chamber such as a nitrogen-inflated accumulator vessel, to devices which undergo plastic deformation, comprising for example cellular materials or honeycomb-type structures which undergo deformation by buckling, or arrangement involving successive breakages of various materials or elements such as hole-bearing tubes wherein the holes suffer deformation when the tubes are subjected to a buckling force, tubes which are engaged one within another such that the inner tube tears the outer tube when it is driven into the latter, or such that the external tube successively cuts off collars or rings which are fixed with respect to the internal tube and which are distributed axially on the periphery of the internal tube.

The characteristic which is common to all these force threshold elements is that the travel movement of the movable end portion which bears thereon begins only as from a substantial level of force applied, which is markedly higher than the forces to which the damper is subjected in operation at normal landing speeds, that the travel movement occurs completely without a substantial increase in said force so that the efficiency in respect of energy of said threshold elements is sufficient, and that the threshold elements function between the "elastic limit" level and the "breakage" level of the adjacent structures so that the threshold elements permit the damper to operate as a force limiting means, the load transmitted by the damper to the adjacent components of the undercarriage or the aircraft structure remaining limited irrespective of the speed of movement of the damper rod into the cylinder.

Preferably however the force threshold element comprises a high-pressure resilient return chamber, the expansion of which is braked by an expansion-mode throttle valve so as to avoid rebounding or bouncing in a damper which is capable of returning to the initial condition after displacement of the movable end portion.

In a particular embodiment, corresponding to a damper jack assembly which can perform the function of a raising and "dropping" jack, the cylinder comprises a second hydraulic fluid chamber wherein a jack rod which is mounted slideably and sealingly defines respectively by means of its inside face and its outside face, a lowering chamber and a raising chamber which can be supplied with hydraulic fluid in order respectively to provide for extension and retraction of the jack rod from or into the second chamber of the cylinder. In a first version, it is possible for the first chamber, the threshold element and the second chamber to be disposed successively in the cylinder, with the first chamber being delimited between the end of the damper rod which is received in the cylinder and the movable end portion, and the second chamber being separated from the threshold element by a fixed transverse wall portion of the cylinder.

In accordance with a preferred embodiment of this first form of the invention, a separator piston which is mounted slideably and sealingly within the jack rod separates the lowering chamber from an adjacent volume of hydraulic fluid which is retained in the second chamber and which is in communication with the first chamber through a hollow rod carried by the fixed transverse wall portion of the cylinder, passing through the threshold element, and around which the movable end portion is mounted slideably. In this way, the hydraulic fluid which provides the damping function is separated from the fluid contained in the operating circuit of the jack for controlling retraction or extension of the jack rod. In addition,

it is possible to use the travel movement of the jack as over-travel in respect of the damper, for the same length of damper jack assembly, and this is particularly advantageous.

In a second form of the invention, suitable for making dampers in the form of damper jack assemblies, the first chamber is delimited between the end of the damper rod, which is received in the cylinder, and a fixed end portion of the cylinder which is provided with passages communicating with an adjoining volume of hydraulic fluid which is contained in an adjoining chamber which also receives the force threshold element.

The adjoining chamber may be either an annular chamber of the cylinder, which is disposed around the first chamber and in which the movable end portion is in the form of an annular slideably mounted piston, or it may be contained in a bottle or vessel which is external to the cylinder and in which the movable end portion is slideably mounted.

However, in the case of a damper jack assembly according to the second form of the invention, it is advantageous for a separator piston which is mounted slideably and sealingly in the rod of the jack to separate the lowering chamber from a volume of hydraulic fluid which is disposed in the second chamber and in the adjoining chamber, which open directly into each other, said volume being in communication with the first chamber through a hollow rod carried by the fixed end portion, passing through the adjoining chamber and the force threshold element which is housed therein, and around which the movable end portion is slideable, thereby in this case also to separate the hydraulic damping fluid from the fluid of the jack operating circuit, and so as to be able to use the travel movement of the jack as a damper travel in an arrangement of the same overall length.

Finally, in all the embodiments, it is advantageous for a retraction piston to be mounted slideably and sealingly on the one hand within the first chamber of the cylinder and on the other hand around the end of the damper rod which is received in the cylinder, in order to define with the cylinder a retraction chamber which is capable of being supplied with hydraulic fluid in order to apply the retraction piston against an abutment which is fixed with respect to the damper rod, and to cause retraction of the damper rod into the first chamber of the cylinder, which, possibly in combination with retraction movement of the rod of the jack into the second chamber of the cylinder, in the case of a damper jack assembly, makes it possible for the arrangement to be of minimal length, corresponding to the undercarriage retracted position.

The invention is diagrammatically illustrated by way of example with reference to the accompanying drawings in which:

Figure 1 shows views of two suspension dampers according to the invention in axial half-sections, one damper corresponding to the left-hand half-section and the other corresponding to the right-hand half-section;

Figure 2 shows a first form of a suspension damper according to the invention with a piston for retraction of the damper rod, being a development of the damper shown in the left-hand half-section of Figure 1;

Figures 3 and 4 show two embodiments in accordance with a second form of a suspension damper according to the invention with a damper rod retraction piston;

Figure 5 shows an embodiment of a suspension damper according to the invention which has damper over-travel, being achieved by development of the damper shown in Figure 2; and

Figure 6 shows another embodiment of a suspension damper according to the invention with damper over-travel.

Referring to Figure 1, a suspension damper for an aircraft undercarriage train comprises a damper rod 1 which is to be fixed to the structure of an aircraft by a mounting 2 at its upper end, and which is mounted slideably and sealingly in a first chamber 3 for hydraulic fluid, such as oil, of a cylinder 4 which is to be fixed to the wheels or to a swinging arm of the undercarriage by means of a mounting 5.

The end of the rod 1 which is received in the chamber 3 of the cylinder 4 carries a damper piston 6 which is mounted slideably on the outer surface of a co-operating counter-rod 7 which at its other end has a movable end portion 8 mounted slideably and sealingly within a lower part 9 of the cylinder 4. The counter-rod 7 passes axially through the first chamber 3 and its free end has axially extending grooves 10 therein. The interior of the rod 1 defines a pressure gas chamber 11 which is adjacent to a volume of oil 12 which is in communication with the interior of the chamber 3 by way of permanent compression-mode throttle orifices 13 and by way of a flow orifice which is of larger section, relative to the orifices 13, and is defined by the axial grooves 10, as long as the piston 6 is co-operating with the grooves 10, and also, possibly, by way of diaphragms provided by an annular valve 14 overlying the orifices 13 for braking an expansion mode of the chamber 11, the movement of the valve 14 being limited, when the damper is subjected to compression force, by a radial internal abutment 15 of the rod 1, while a radial external abutment 16 on the rod 1 limits the outward movement of the rod 1 from the chamber 3 under the thrust force of the pressure gas chamber 11. The movable end portion 8 separates the chamber 3 from a force threshold element formed by a pressure gas chamber 17 in which the pressure is markedly higher than that in the chamber 11, and which forms the high-pressure chamber of a double-chamber oleo-pneumatic damper, expansion of which is braked by an expansion-mode throttle valve which, in the same way as the valve 14, is formed by an annular disc apertured with at least one diaphragm facing a flow orifice, the movements of which are limited

by an abutment. In the left-hand half-section in Figure 1, a valve 18 for throttling the flow of fluid in the expansion mode of the high-pressure chamber 17 is disposed in an annular chamber 19 defined between the enlarged part 9 of the cylinder 4, the movable end portion 8 and a sleeve 20 for guiding the movable end portion 8 and being slideable along the inside surface of the chamber 3. The annular chamber 19 is freely supplied with fluid by way of a passage 21 provided at the base of the sleeve 20, when the movable end portion 8 is displaced in the direction of compressing the high-pressure chamber 17, the valve 18 then being applied against a radial external abutment 22 on the sleeve 20 which, by bearing against a shoulder 23 which separates the wall portion of the chamber 3 from the wall portion of the enlarged part 9 of the cylinder 4, defines the rest position of the movable end portion 8 under the thrust force of the high-pressure chamber 17.

The action of braking expansion of the high-pressure chamber 17 can alternatively be effected positively as shown in the right-hand half-section in Figure 1, by an expansion-mode throttle valve 24 disposed in an annular chamber 25 defined between the inside surface of the chamber 3, the outside surface of the end of the rod 1 which is received in the cylinder 4, and a radial external ring 26 on the damper piston 6, which is provided with at least one free flow orifice 27 and which is slideable against the inside surface of the chamber 3, the movements of the valve 24 in the chamber 25 being limited by the abutment 16 and the ring 26.

The damper comprising the above-described structure operates in the following manner: at any landing speed there occurs a first travel movement of the rod 1 in the cylinder 4, without any damping action, by virtue of the oil flowing freely from the chamber 3 towards the volume 12 by way of the grooves 10 which make it possible for forces due to throttling of the oil, not to be superimposed on the forces due to the inertia of the non-suspended components, when said components are subjected to acceleration with respect to the structure of the aircraft. The grooves 10 thus make it possible to delay the commencement of damping. If the landing is at a normal vertical speed, of the order of 3 m/s, damping is effected by the throttling action through the orifices 13 in the piston 6, in respect of the oil which is displaced from the chamber 3 by the inward movement of the rod 1 and which causes compression of the low-pressure chamber 11, the valve 14 being lifted from its seat and applied against the abutment 15. As the orifices 13 are calibrated for such normal vertical speeds, the pressure in the chamber 3 does not rise sufficiently to reach the pressure existing in the high-pressure chamber 17, so that the movable end portion 8 is not displaced. On the other hand, if the vertical speeds are higher, of the order of 6 m/s, the result is simultaneously a throttling action by means of the orifices 13 and a pressure in the chamber 3 which reaches the pressure existing in the chamber 17, which pressure constitutes a threshold above which the movable end portion 8 is displaced inwardly. The result therefore is simultaneously an inward movement of the rod 1 into the chamber 3 and an inward movement of the movable end portion 8 into the enlarged part 9 of the cylinder 4. When contact is made with the ground at a speed of the order of from 10 to 13 m/s, for example in a crash landing, the orifices 13 are of a section which is insufficient to permit a sufficient flow of oil into the volume 12. The pressure therefore rises rapidly in the chamber 3 and the movable end portion 8 is displaced as soon as the pressure threshold of the chamber 17 is exceeded. In this configuration, the arrangement operates like a force limiting means which does not provide any substantial additional resistance to the inward movement of the movable end portion 8, irrespective of the speed at which the rod 1 is displaced inwardly of the cylinder 4. This damper also has the advantage that the level of the force at which the movable end portion 8 begins its inward movement is independent of the speed of inward movement of the rod 1 and depends only on the pressure and volume characteristics of the high-pressure chamber 17.

In order to avoid bouncing or rebounding, in all cases expansion of the low pressure chamber 11 is braked by throttling the oil passing from the volume 12 to the chamber 3 by way of the diaphragms of the valve 14 which is applied against the piston 6 and, in every case when displacement of the movable end portion 8 occurs, expansion of the high-pressure chamber 17 is braked, either by the valve 18 throttling the flow of oil from the annular chamber 19 to the chamber 3, or by the valve 24 throttling the flow of oil passing from the annular chamber 25 to the chamber 3, depending on the design of the arrangement, the grooves 10 in the rod 7 also providing a good re-supply of fluid to the chamber 3 and the volume 12 as well as good separation between the gas and the oil for return to the initial conditions.

Referring now to Figure 2, a suspension damper comprises a damper similar to that shown in the left-hand half-section of Figure 1, with a damper rod 31 and a piston 36, containing a low-pressure gas chamber 41 and a volume of oil 42 which communicates with a chamber 33 of a cylinder 34 by way of compression-mode throttle orifices 43, the piston 36 being mounted slideably about a counter-rod 37 which is fixed with respect to a movable end portion 38 which isolates a high-pressure gas chamber 47 in an enlarged part 39 of the cylinder 34.

This damper operates in the same manner as the damper shown in Figure 1, with the braking action in the expansion mode of the high and low pressure chambers 47 and 41 being provided respectively by valves 48 and 44, the only significant difference being that the movement of the rod 31 out of the chamber 33 is limited not by

an abutment bearing against the cylinder 34 but against a retraction piston 58 which is mounted slideably and seelingly both around the rod 31 and against the inside surface of the chamber 33. Thus, with the surface of the chamber 33, the retraction piston 58 defines a retraction chamber 59 which can be supplied with oil by way of a conduit 60 in order to cause retraction of the rod 31 into the cylinder 34, thus loading the damper, that is to say, compressing the low-pressure chamber 41, by the retraction piston 58 bearing against an abutment 46 of the piston 36 of the rod 31. The damper also includes a jack assembly in that it has a jack rod 61 which is fixed with respect to a mounting 35 and which is mounted slideably and sealingly within a second chamber 62 of the cylinder 34. By means of its inside surface, the jack rod 61 defines a lowering chamber 63 and, by means of its outside surface, the rod 61 defines a raising chamber 64. The chamber 63 and 64 can respectively and alternately be supplied with oil by way of conduits 65 and 66 which are connected to an hydraulic circuit of the aircraft, by way of suitable distributors or valves, which can also supply fluid to the retraction chamber 59 by way of the conduit 60. The lowering chamber 63 is separated from the high-pressure gas chamber 47 by means of a fixed transverse wall portion 67 of the cylinder 34 so that the chambers 33, 47 and 63 are disposed in succession in the cylinder 34. The suspension damper including the jack assembly for the undercarriage of an aircraft comprising the above-described structure, as already mentioned, provides the damper function under the same conditions as the arrangement of Figure 1, but it also makes it possible either for the undercarriage to be raised in the "undercarriage up" position when the retraction and raising chambers 59 and 64 are supplied with oil and the lowering chamber 63 is emptied, the arrangement being of minimal length by virtue of the jack rod 61 being retracted into the second chamber 62 and the damper rod 31 being retracted into the first chamber 33, or for the undercarriage to be lowered into the "undercarriage down" position when the retraction and raising chambers 59 and 64 are emptied and the lowering chamber 63 is filled, the arrangement being of maximum length as shown in Figure 2, or for the aircraft which is resting on its undercarriage train after landing to be "dropped", by supplying oil to the raising chamber 64 and emptying the lowering chamber 63, the position of the damper portion under a static load being unchanged.

The damper jack assembly shown in Figure 3 is substantially identical in operation to that shown in Figure 2, the only significant difference from the structural point of view being that a first chamber 73 of a cylinder 74 in Figure 3 is defined between the end of a damper rod 71, which is inward of the chamber 73, and a damper piston 76 on the one hand, and a fixed end wall portion 107 of the cylinder 74 on the other hand, the transverse wall portion 107 acting as the fixed end portion of the chamber 73 which it separates from a lowering chamber 103 which is defined by a jack rod 101 which is slideable in a second chamber 102 of the cylinder 74. The fixed end wall portion 107 has a radial passage 111 which opens into a central aperture 112 provided at the base of a counter-rod 77 which is fixed with respect to the fixed end wall portion 107, and the central aperture 112 itself communicates with the chamber 73 by way of two radial passages 113 provided in the counter-rod 77, whereby the chamber 73 communicates with an adjoining volume 114 of oil contained in a further chamber 79 in the form of an annular chamber on the cylinder 74, which is disposed around the first chamber 73 and in which the movable end portion is in the form of an annular piston 78 which is mounted slideably and sealingly and which separates the adjoining volume of oil 114 from a high-pressure gas chamber 87. In this particular embodiment which makes it possible to reduce the lengthwise dimension compared with the embodiment of Figure 2, an expansion-mode braking valve 88 for the high-pressure chamber 87 is disposed in an enlarged portion of the central aperture 112 into which the radial passage 111 opens. It will be appreciated that the damper rod 71 comprises a low-pressure gas chamber 81, an adjacent volume of oil 82 and a valve 84 for braking in the expansion mode of the chamber 81, compression-mode throttle orifices 83, a piston 98 and a retraction chamber 99, and, at the location of the jack rod 101, a raising chamber 104.

The damper jack assembly shown in Figure 4 is also substantially identical in operation to the assemblies shown in Figures 2 and 3, the only significant difference, from the point of view of structure, from the assembly shown in Figure 3, is that an adjoining chamber 129 is in the form of a bottle or vessel of generally cylindrical shape, which is external to a cylinder 124 and in which a movable end portion 128 is a separator piston which is mounted slideably and sealingly in the vessel and which separates a high-pressure chamber 137 from an adjoining volume of oil 164 which is connected to a first chamber 123 by way of a connecting conduit 165, a radial passage 161 in a fixed end wall portion 157, a central aperture 162 and radial apertures 163 which are provided in the base of a counter-rod 127 carried by the fixed end wall portion 157. A damper rod 121 is slidable into the cylinder 124 and a retraction piston 148 co-operates with a retraction chamber 149. This embodiment provides the same advantage as the embodiment of Figure 3, but it also appears to be of simpler design from the point of view of the structure of the cylinder 124.

Figure 5 shows a damper jack assembly which constitutes a development of the embodiment shown in Figure 2. A separator piston 208 is mounted slideably and sealingly with a jack rod 201 in which the piston 208 is retained by an internal radial end abutment 216 to separate a lowering chamber 203 from an adjacent volume 210 of oil contained in a second chamber 202 of a cylinder 174, and which is also in communication

with a first oil chamber 173 by way of a hollow rod 217 carried by a fixed end wall portion 207 of the cylinder 174 and passing through a high-pressure chamber 187 provided in an enlarged part 179 of the cylinder 174, the free end of the hollow rod 217 opening within a blind bore 218 formed in a counter-rod 177 and connected to the chamber 173 by radial passages 213 which are provided in the base of the counter-rod 177 which is carried by a movable end portion 178. The movable end portion 178 is itself mounted slideably and sealingly around the hollow rod 217. In addition, a raising chamber 204 is not defined between the outside surface of the jack rod 201 and the inside surface of the second chamber 202, but between the latter and an annular piston 209 which is mounted slideably and sealingly on the one hand within the chamber 202 and on the other hand around the jack rod 201 which the annular piston 209 can retract into the chamber 202 by bearing against an external radial abutment 219 on the rod 201 when the raising chamber 204 is supplied with oil by way of a conduit 206. Starting from the "undercarriage down" position in which the damper jack assembly is of maximum length (as shown in Figure 5), a retraction chamber 199 and the reaction chamber 204 being empty and the lowering chamber 203 being full, the arrangement is moved into the "dropped" position by supplying oil to the raising chamber 204 by way of the conduit 206 and emptying the lowering chamber 203 by way of a conduit 205, and the arrangement moves in the "undercarriage up" position by also simultaneously supplying oil to the retraction chamber 199 by way of a conduit 200 so that a retraction piston 198 pulls a damper rod 171 into the interior of the chamber 173, thus loading the damper; it will be appreciated that the components can be moved in the opposite direction, from one position to the other, by reversing the movements of the oil.

As the volume of oil 210 which is contained in the chamber 202 is in constant communication with the oil in the chamber 173, the pressure obtaining in the chambers 173 and 202 will be the same so that, upon landing, and if it is assumed that the damper rod 171 and the jack rod 201 are of similar sections, then almost simultaneously the damper rod 171 will be displaced into the chamber 173 and the jack rod 201 will be displaced into the chamber 202, the oil displaced by the rod 201 and the piston 208 flowing into the chamber 173 whose oil is throttled through orifices 183 and increases a volume 182 in the damper rod 171, compressing a low-pressure chamber 181. This therefore provides a damper jack assembly which has an extended damping travel, the travel of the jack rod 201 or the "dropping" travel of the damper jack assembly being used as a damping over-travel movement for normal vertical landing speeds in respect of which there is no movement of the movable end portion 178, or for higher speeds in respect of which there is both damping and displacement of the movable end portion 178. This construction is advantageous as it provides both a greater damper travel in an arrangement of the same overall length as that of the arrangement in Figure 2, and separation as between the oil of the operating circuit which is connected to the lowering chamber 203, the raising chamber 204 and the retraction chamber 199, and the oil of the damper in the chambers 202 and 173 and in the damper rod 171.

Figure 6 shows a damper jack assembly which is generally equivalent to that shown in Figure 5, in regard to the mode of operation and the advantages attained, but which is of modified structure in its central portion: a counter-rod 227 which extends axially in a chamber 223 of a cylinder 224 and around which a piston 233 of a damper rod 221 is slideable, is carried by a fixed end wall portion 257 which separates the chamber 233 from a high-pressure chamber 237, and is extended by a hollow rod 267 which passes through the high-pressure chamber 237 and which opens into a volume of oil 260 which is housed in a second chamber 252 and the part of an adjoining chamber 229 which opens directly to the chamber 252 and which is separated from the high-pressure chamber 237 by a movable end portion 228 which is mounted slideably about the hollow rod 267. The volume of oil 260 communicates with the chamber 223 by way of the central passage of the rod 267, which opens at the base of the counter-rod 227 into the chamber 223 by way of a passage 263, so that, under the same conditions as described above, the "dropping" travel movement or travel of a jack rod 251 is used as a damper over-travel movement. The oil of the operating circuit and the damper oil are also separated by the provision of a separator piston 258 and annular raising and retraction pistons 259 and 248 respectively. In this embodiment, the braking action in respect of expansion of the high-pressure chamber 237 is provided by producing a throttling action, through the diaphragms of a valve 238 carried by the movable end portion 228, opposite flow orifices 241 provided in an external radial ring 270 on the movable end portion 228, in respect of the oil which occupies a volume 271 and which is displaced from an annular chamber 272 defined by a side 273 of the movable end portion 228 and an upper edge portion 274 thereof which is bent over in an enlarged chamber 272 of the adjoining chamber 229.

In the different embodiments shown in Figures 1, 2 and 5 wherein the counter-rod 7, 37 or 117 is movable, as it is carried by the movable end portion 8, 38 or 178, it will be found that the movable end portion is disposed in enlarged parts 9, 39 or 179 of the cylinder, the cross-sections of which enlarged parts are always greater than the cross-sections of the damper rods 1, 31 or 171 so that, following the initial inward movement of the damper rod 1, 31 or 171 on the counter-rod 7, 37 or 177, by virtue of the axial grooves in the latter, and if the movable end portion is displaced, the

travel movement of the latter is less than the travel movement of the damper rod along the central counter-rod, and the inward movement of the damper rod on the central counter-rod therefore increases, whether the counter-rod is or is not movable.

Moreover, Figure 1 also shows in dash-dotted lines, an alternative embodiment which differs from that shown in solid lines only by virtue of the fact that a counter-rod 7′ is fixed with respect to the end portion of the cylinder 4, while a movable end portion 8′ which replaces the end portion 8 is also mounted slideably and sealingly about the counter-rod 7′ and is thrust against a radial abutment 28 which is fixed with respect to the counter-rod 7′, in the rest position, under the action of the high-pressure chamber 17. This modified arrangement, although having a fixed counter-rod 7′, is substantially identical in its mode of operation to the arrangement shown in solid lines.

It should also be noted that it is possible to produce dampers wherein the damper rod 31, 71 and 121 can be retracted into the cylinder 34, 74 and 124 if the arrangement retains the retraction piston 58, 98 and 148 and the retraction chambers 59, 99 and 149 of the arrangements shown in Figures 2, 3 and 4, eliminating the jack portion below the fixed wall portions 67, 107 and 157. Conversely, it is possible to produce damper jack assemblies which permit "dropping" but not retraction at the level of the damper, by retaining the jack portion and eliminating the retraction pistons, in Figures 2 to 6.

In their damper or damper jack assembly forms, with or without retraction of the damper rod, the assemblies according to the invention will be used to advantage on helicopter undercarriage trains for limiting the effects thereon of a crash landing and so as to permit landings to be made, without damage, at vertical speeds which are markedly higher than those which have previously been allowed.

CLAIMS

1. A suspension damper comprising a damper rod which is mounted slideably and sealingly within a first hydraulic fluid chamber of a cylinder and which contains a low-pressure resilient return chamber adjacent to a volume of hydraulic fluid which is in communication with the first chamber of the cylinder by way of at least one compression-mode throttle orifice provided in a piston carried by the end of the damper rod which is inward of the cylinder, expansion of the low-pressure return chamber being braked by an expansion-mode throttle valve, wherein the hydraulic fluid pressure obtaining in the first chamber is applied to a movable end portion which itself bears against a force threshold element permitting a travel movement of the movable end portion, when the damper is subjected to a compression load, as from a force greater than a given threshold, and independently of the speed of inward movement of the damper rod into the cylinder.

2. A suspension damper according to claim 1, in which the force threshold element is formed by a high-pressure resilient return chamber, expansion of which is braked by an expansion-mode throttle valve.

3. A suspension damper according to claim 1 or claim 2, in which the cylinder includes a second hydraulic fluid chamber wherein a jack rod which is mounted slideably and sealingly defines respectively by means of its inside surface and its outside surface, a lowering chamber and a raising chamber which can be supplied with hydraulic fluid in order respectively to produce extension and retraction of the jack rod from or into the second chamber of the cylinder.

4. A suspension damper according to claim 3, in which the first chamber, the force threshold element and the second chamber are disposed in succession in the cylinder, the first chamber being delimited between the end of the damper rod which is received in the cylinder and the movable end portion and the second chamber being separated from the force threshold element by a transverse wall portion of the cylinder.

5. A suspension damper according to claim 4, in which a separator piston which is mounted slideably and sealingly within the jack rod separates the lowering chamber from an adjacent volume of hydraulic fluid which is retained in the second chamber and which is in communication with the first chamber by way of a hollow rod carried by the transverse wall portion of the cylinder and passing through the force threshold element, and around which the movable end portion is mounted slideably.

6. A suspension damper according to any one of claims 1 to 3, in which the first chamber is delimited between the end of the damper rod which is received in the cylinder and a fixed end portion of the cylinder which is provided with passages for communicating with an adjoining chamber which also accommodates the force threshold element.

7. A suspension damper according to claim 6, in which the adjoining chamber is an annular chamber on the cylinder around the first chamber, and in which the movable end portion is in the form of a slideably mounted annular piston.

8. A suspension damper according to claim 6, in which the adjoining chamber is contained in a bottle which is external to the cylinder and in which the movable end portion is slideably mounted.

9. A suspension damper according to claim 6 when appendant to claim 3, in which a separator piston which is mounted slideably and sealingly in the jack rod separates the lowering chamber from a volume of hydraulic fluid which is disposed in the second chamber and in the adjoining chamber which open directly one to the other, the volume being in communication with the first chamber through a hollow rod carried by the fixed end portion and passing through the adjoining chamber and the force threshold element which is

disposed therein, and about which the movable end portion is slideable.

10. A suspension damper according to one of claims 1 to 9, in which a retraction piston which is mounted slideably and sealingly on the one hand in the interior of the first chamber of the cylinder and on the other hand around the end of the damper rod which is inside the first chamber of the cylinder defines with the cylinder a retraction chamber which can be supplied with hydraulic fluid for applying a retraction piston against an abutment which is fixed with respect to the damper rod and causing retraction of the damper rod into the first chamber of the cylinder.

11. A suspension damper substantially as hereinbefore described and illustrated with reference to any of the accompanying drawings.

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